



## The Pedagogy of Building Information Modelling

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# The Pedagogy of Building Information Modelling

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**ABSTRACT:** Building Information Modelling (BIM) has been made mandatory for all UK Government contracts over the European threshold. This has led to its hurried adoption within Higher Education Institutions with many adopting similar pedagogies to those used for teaching CAD. This paper seeks the views of the BIM Academic Forum, set up to establish a common BIM curriculum in the UK and Ireland on the pedagogies that should be adopted in BIM teaching. It finds that as BIM is more than just a technology, and as such a different pedagogical approach to that used in CAD teaching should be taken. This approach while in the main constructivist, learning by doing, should also have components taught using didactic methods. The findings further indicate that educators need support from accreditation panels and industry in adopting this new technology which will continue to evolve over the next number of years.

**KEY WORDS:** Pedagogy; Civil Engineering; BIM; CAD.

## 1 BACKGROUND

Pedagogy is defined as an identified activity carried out by a person (normally a lecturer) planning to supplement learning development in another individual [1]. Bernstein (2000) goes further, defining pedagogy as a sustained process where an individual or group acquire new or develop existing forms of knowledge from somebody or something deemed to be an appropriate provider/evaluator [2].

In order to deliver necessary skills required by industry, Universities have been investing in software to deliver Computer Aided Design (CAD) and Building Information Modelling (BIM). Pedagogical practices need to be considered to include these new challenges and requirements from industry with regards to shifting stipulations of competency required from fresh graduates leaving tertiary education [3]. It cannot, however, be just the provision of hardware and software but must include the pedagogical base behind how the material is delivered. Active learning is where both the educator and learners cooperate to formulate and achieve a combined experience whereby the learner has an active role [4].

Emphasis is placed on a student centred learning environment which aids students in controlling their own learning. The active learning experience increases enthusiasm and motivation towards learning [5]. What has not been fully researched is application of different pedagogies to BIM teaching.

## 2 PEDAGOGICAL STRATEGIES

### 2.1 Pedagogical Strategies Spectrum

There are three relevant positions on the learning process; behavioural, cognitive, and constructivist [6]. These emanate from the two schools of Greek philosophy; Plato's work producing rationalism and Aristotle's work producing empiricism. Aristotle considered learning through how people

think or behave through imitation of particulars. Constructivism developed from this through the work of Paigent [7].

### 2.2 Constructivism

Hein (1991) indicated that constructivism considers: *that there is no knowledge independent of the meaning attributed to experience (constructed) by the learner, or community of learners* [8]. Plato is the opposite end of the didactic spectrum where a theoretical framework is constructed [9]. Constructivism therefore does not focus on an ontological reality but on a constructed reality. Cognitive theory, dealing with the learner, is the basis for the constructivist line of thought; the nature of the learner. Constructivism has been the approach suggested for software use by a number of organisations as participation is one of the best pedagogical approaches to teaching engineering courses [10, 11, 12]. From a technology standpoint, it has been suggested by many that technology can support the use of constructivist approaches to teaching and learning [13, 14]. Constructivism has led to the term 'problem-based learning' [15], which is ideal for the teaching of BIM. However, educators in traditional educational environments are not always positive regarding teaching aided by technology [16].

### 2.3 Behaviourism

A behaviourist approach to education differs, as behaviourists describe learning as a process of connecting stimuli and responses [17]. Conveyance of instructions, constant repetition of outcomes and previous experiences are deemed to be the most important objectives within teaching [18]. It is suggested that these activities produce modifications in a student's behaviour through these peripheral stimuli [17]. The learner is therefore reactive to conditions in the environment rather than discovering the environment for themselves [6]. So a behaviourist only looks at the final result

of learning and not the actual learning experience. Therefore, behaviourism has influenced traditional approaches to learning such as didactic education.

Critics suggest that an inactive learning environment for the student provides little motivation to learn and thus the learning is not as deeply embedded. However, according to Schaffer and Small (2004) [19], the integration of computers with small and large group didactic instruction allows optimal use of resources in addition to conforming to accepted theories of adult learning. This approach is well-accepted by students [19]. Traditionally education has focused on behaviourist pedagogies [20].

The fact that different parts of the same program should have more didactic content than others [21] raises the issue that the pedagogical approach to BIM needs to be examined. This paper will examine whether the more instructive behavioural approach is necessary to sit alongside the constructivist theory in relation to BIM-related teaching.

### 3 CAD AND BIM TEACHING

#### 3.1 Differences between CAD and BIM

CAD has become an industry standard tool for the production of construction drawings across the architecture, engineering and construction (AEC) sectors. CAD was developed and became an industry standard around 30 years ago [22]. However, the capabilities and capacities of computers have moved on. Software packages have become more sophisticated. Drawing packages have the capability of effortlessly producing 3D models. This led to the development of BIM which allows users to include intelligent information about each entity within the 3D model. Van Nederveen et al. (2009) [23] acknowledges that BIM contains this information in the 3D model, stating BIM is about: *the building itself as well as its components and comprises information about properties such as function, shape, material and processes for the building life cycle*. Instead of models being created from line drawing through CAD, projects are constructed from virtual elements such as walls, foundations, windows, doors and roofs. The creation of models from elements is known as object-based modelling whereas CAD produced line-based models are known as entity-based models [24].

#### 3.2 Teaching Pedagogy for CAD and BIM

The move from CAD to BIM is a paradigm shift creating many opportunities and challenges [25]. Macdonald (2011) [26] argues that there is little pedagogical difference in approach between manual draughting and 2D CAD. However, she argues that, due to its collaborative nature, BIM sits apart. As a result some suggest that BIM should be taught in cooperation with a studio or via small design challenges. They argue that similar to CAD, students are not attending to: *learn how to draw lines, arcs, circles, etc., but to comprehend the procedural nature of the building design process* [27]. Therefore, an amount of didactic teaching on the process is required prior to the problem-based learning approach to model building. Ibrahim (2007) [28] argues that: *training required for BIM based CAD should focus on the change in the work flow rather than the application interface and functionalities*. Therefore, it is very different than teaching CAD and less didactic in nature. As there is a disagreement on

the means of approach and the comparisons between CAD and BIM, this paper seeks to fill that knowledge gap by gathering quantitative and qualitative data from BIM academics regarding the preferred methods to be adopted.

## 4 METHOD

### 4.1 Survey sample

In 2011, the BIM Academic Forum (BAF) was founded to provide guidance and consistency in BIM adoption across Higher Education Institutions (HEIs). They were tasked with the provision of a framework to indicate the different aspects of BIM to be taught at each level [29]. The BAF incorporates academic representatives from across UK and Ireland. Currently it contains over 30 members from 60 different institutions [29]. After the telephone sift, 38 unique institutions were identified. A representative from each was then asked to participate and 24 agreed to do so. Responses from a structured on-line questionnaire were collated from BAF members willing to respond, as it was deemed these academics held the expert knowledge relating to BIM teaching. Their responses were both qualitative and quantitative in nature.

### 4.2 Survey software

Limesurvey™ software was used to supply the piloted structured on-line questionnaire and also the final version. Limesurvey™ generates unique tokens specific to each individual participant. These tokens ensure through the survey management tool that responses can only be submitted from the designated sample. Responses are stored on the software on-line database for analysis purposes. The quantitative responses were analysed automatically through the Limesurvey™ software. However, qualitative responses were exported from this software and analysed in NVIVO™, which provided a certain degree of quantitative analysis of the qualitative responses.

### 4.3 Survey response and validity

From the initial population size, 24 BAF members agreed to participate in the survey. Fifteen responses were submitted where the survey was completed in their entirety. Partially completed responses were ignored. On the basis of questionnaires that were completed in their entirety a 62.5% response rate was attained. The sample size was calculated using the Krejcie and Morgan (1970) [30] method which indicates that for such a small sample, all HEIs are required for validity. A minimum response rate of 50% is required for analysis purposes [31]. With 15 responses received (i.e. greater than the 12 required), subsequent analysis met this criterion.

### 4.4 Expertise of the participants in BIM

BIM expertise is measured by the UK Government via the Bew and Richards Triangle [31] on four levels, labelled 0-3. Level 0 is basically 2D CAD and level 3 is the single fully integrated model. The UK Government requires level 2 on all its contracts by 1<sup>st</sup> April 2016 [32]. The skill level of the academics teaching BIM and sitting on the academic forum should therefore be at or above this level.

Table 1. Academic Skill Level on Bew and Richards Triangle

On the Bew and Richards scale what level of BIM have you had experience working to?		
Answer	Count	Percentage
Level 0	0	0%
Level 1	1	7%
Level 2	9	60%
Level 3	5	33%
No answer	0	0%

It can be seen from Table 1 that the expected level of expertise existed in those who sat on the BAF. Sixty percent (60%) were already operating to the UK Government's required level, with an additional third operating above this level. Only a single response was obtained that did not meet this level equating to 7% of the sample. This indicates that the expertise of those responding to the questionnaire was to the correct level.

The results further provide evidence that HEIs are implementing BIM to a minimum of level 2 throughout their institutions. This is the level required in the UK Government Construction Strategy Report [32].

## 5 FINDINGS

### 5.1 Pedagogical Approach to teaching BIM

From the literature review at the commencement of this paper it was suggested that constructivism paradigm was the approach best suited to the teaching of BIM and CAD on engineering courses [10,11,12]. The results of the questionnaire confirm this. Indeed, Table 2 below indicates that all of the academics agreed that the constructivist approach should be adopted for BIM teaching.

Table 2. Constructivism and teaching BIM

Do you consider that the constructivist approach to BIM teaching is the correct way to approach BIM teaching?		
Answer	Count	Percentage
Yes	15	100%
No	0	0%
No answer	0	0%

This unanimous result was followed by a qualitative question probing the reason for the response shown in Table 2 and allowing comment on other approaches to BIM teaching. Eight of the fifteen responses (53.4%) suggested that while the constructivist approach was chosen, it could not be used in isolation. It was suggested that *a mix of methods, balanced or hybrid approach* was required. They further suggested that a *learning by doing approach* should be *filtered for the correct approaches* to ensure that a *change mentality* was adopted. They suggested the didactic element should include:

1. *Guidance on best practice;*
2. *Guidance on online etc. resources that can be accessed by individuals;*

3. *Guidance as elements can be omitted. Also the collaborative approach can be missed out, so exposure to current thinking is necessary;*
4. *Foundational aspect to learning mechanics of the application; once this is overcome constructivism principals will apply.*

However, the qualitative reasoning for the result in support of the constructivist approach centred on the fact that students need to learn BIM by *doing*. It was suggested that students need to have: *the same challenge as the construction industry faces now*. A similar approach can be taken in adopting problem-based learning where academics: *define outputs and let students explore best ways of achieving same*. Furthermore, independent learning by doing was suggested in the following response:

*Students need to understand what the problem is and determine the appropriate process and tool. I believe if students appreciate that they need to improve communication between disciplines to ensure appropriate information is generated at the right time, then PAS 1192 et al. become part of their solution; they don't get it if we tell them!*

Even more support was given to BIM being taught through project-based learning as *'chalk and talk' does not work in this context*. The collaborative nature of the BIM process was also provided as a reason for: *learning by doing*. *Students normally try to use their own established communication techniques e.g. physical data transfer. After a while they realise that BIM tools transfer the same data better*. The findings indicate, therefore, that while the constructivist pedagogical approach should be adopted, it should not be used exclusively and that the majority of academics consider a balanced approach of different pedagogies should be used.

### 5.2 Pedagogical approaches to CAD and BIM

While identification of specific content for BIM modules at Levels 4-7 is the primary objective of BAF, the worked discussed to this point shows that it is also extremely important to identify an optimal pedagogy. While there is limited research regarding optimal approaches to BIM-related pedagogy, there is a wealth of experience in CAD teaching. While the literature review concluded that the two systems are very different, results shown in Table 3 indicate that the majority of respondents (87%) consider that the conclusions of Ibrahim (2007) [28] were fully justified and a different approach should be taken to the teaching of BIM than that previously adopted for CAD.

Table 3. Pedagogical approach similarities - CAD and BIM

Do you consider that the same pedagogical principles that are used in the teaching of CAD should also be applied to the teaching of BIM?		
Answer	Count	Percentage
Yes	2	13%
No	13	87%
No answer	0	0%



A further qualitative-style question elicited the rationale behind this outcome. The breadth of material and the *wider scope* of BIM application were the main reason offered. It was stated that BIM is: *not just a technical solution, so it differs significantly from teaching CAD*. Furthermore: *the value network of BIM is far beyond that of CAD and this will reflect into the teaching and learning*. While two of the responses acknowledged some similarities between BIM and CAD teaching, nine of the fifteen responses (60%) identified the much wider aspect of BIM teaching with the following main differences provided:

1. *Procurement and 4 & 5D BIM are differing subject areas;*
2. *Collaboration/downstream use of information, standards and processes must be taught in conjunction with practical modelling skills;*
3. *Less reliance on 'software training' and more on the individual student learning the software and applying it through projects/cases;*
4. *BIM is more an integration of different design and planning skills. For example, it puts quantities into the middle of the design. Therefore, collaboration and communications are essential;*
5. *Drawing and graphical representation is fundamentally different to virtual modelling. The latter requires advanced knowledge of the discipline.*

Three of the responses concentrated on the need for *theory* in addition to *practice* in the teaching of BIM in order for it to be understood fully. There was also an acknowledgement that: *BIM can radically change the way students learn and think. However, there is not enough evidence or details about how this has changed. Therefore, our current way of delivery has just been incremental. Radical change in HEIs takes time. We, as HEIs, are slow in responding*. Therefore, there is a further need for those in HEIs to change the methods and practice of BIM teaching in a tertiary education context.

Providing a synthesis on respondents' views above, it can be seen that CAD teaching processes have limited application in regard to utilising them for teaching BIM. Didactic approaches need to be adopted for BIM so that in-depth theoretical knowledge is passed to students, in addition to the hands-on approach to teaching a software programme usually adopted when teaching CAD.

### 5.3 Qualitative comments on BIM teaching

Ten further qualitative responses were received regarding approaches that should be taken for BIM teaching and how the BAF can facilitate a best way forward for all HEIs.

The changing nature of the industry and also the requirements and capabilities of BIM have been highlighted by six of the ten responses. The fact that BAF is quite restrictive in its approach was highlighted but acknowledged as the best way forward existing at the minute. One response stated that: *BAF's approach is flawed as it is too limiting in what we can do. It is still best to allow for change to take place and the protocols are still in development and case studies are [sic] still needed to demonstrate best practices*.

Furthermore, the capacity changes of the software itself were identified in the comment: *what we do now may not be the right way to adopt and implement on site*.

The changing nature of the industry and the use of new platforms in the construction industry were also acknowledged in the comment: *we are in the situation of new platforms - mobile and tablet / cloud hosting - becoming more prevalent. This is changing how we build buildings*. However, the fact that not all in industry have adopted BIM-enabled approaches was also acknowledged: *BIM is a testing subject. We still need to promote its adoption*. Support from industry partners in the delivery of teaching was also supported and barriers caused by certain accreditation bodies: *HEIs need to thoroughly discuss the teaching of BIM and accreditation bodies need to be involved in this process. The fast evolving technology, policy and standards together with the lack of involvement by accreditation bodies and limited knowledge of lecturers are making this task really challenging. In the meantime, HE could adopt a practice-oriented approach and use industry lecturers to deliver some of the content*.

Further comments on the teaching provision suggested: *tutorials offered by Whitefrog as a very useful resource and a discrepancy in the approach to the content of modules with some suggesting a blended approach but also incorporated into individual modules whereas others suggested they were trying to embed BIM through the syllabus rather than having too many compartmented specific BIM taught modules, except in Architectural Technology which demands more hands on competency in 3D modelling*.

The collaboration and management aspects of BIM should not be restricted to a single platform bringing the interoperability of the software to the fore. *BIM should be considered as a main framework for managing construction projects effectively and should not be limited to training on software such as Revit and the delivery of a multi-platform data enables learners across the built environment to collaborate with cultural changes to adopt open BIM*. Student involvement across different disciplines and courses has been promoted as best practice.

Feedback was also touched on in relation to the design aspects of BIM with: *the visualisation of the design provides quick and enjoyable feedback and helps students to understand the construction technology involved*.

There still remains, however, some uncertainty around the approach taken with one respondent acknowledging: *whether we have the right approach is difficult to determine. Staff buy-in and coordination is necessary for the correct approach to teaching BIM to be adopted although it has been acknowledged that there are a few BIM champions in various areas*.

The general view of BAF members is, therefore, that practices in BIM teaching is still developing and it will take time to develop an optimum BIM teaching strategy from the specific content to be included at different levels. As such, the best way to teach BIM is still to be fully determined as BIM software capabilities are still developing.

## 6 CONCLUSIONS

This paper examined the pedagogical strategies involved in the teaching of CAD and BIM. It traced the two main pedagogical strategies used for their teaching: Constructivism and Behaviourism. From a BAF perspective it was concluded that the constructivist approach should be the one used in BIM teaching for the software elements. However, the group acknowledged that guidance through didactic teaching was also required.

Furthermore, this research showed that guidance on the best practice, location of online resources and foundational background to the application needs to be delivered in didactic style. Therefore, while the policy of the Joint Board of Moderators (JBM) [10] and others [11, 12] has been proved in the main to be correct, it needs to be widened to encompass the wider BIM remit. The respondents indicated that the 'problem based learning' approach of CDIO [12] is fully supported for the software elements of BIM. However, they also suggested that it should be supplemented with didactic instruction. This differs from the constructivist only approach in much of the documentation and should change the approach to BIM teaching in a HEI context. However, it was acknowledged that HEI's are slow to change and the practice of BIM teaching in a tertiary education context will have to adapt eventually.

The wider aspect of BIM in relation to CAD is also expressed in the findings, as a substantial majority do not consider the same pedagogical approach should be taken to teaching the two systems. BIM should have more didactic teaching elements than CAD due to it being more than a technical solution.

The elements covered by didactic teaching were proposed to be specific discipline knowledge, procurement, standards and processes such as PAS 1192 and quantity take-off. A mixture of styles should therefore be used to communicate BIM in order for it to be understood fully.

The fact that the BAF are trying to produce a method of BIM teaching that will meet the needs of all HEI's as far as content is concerned caused concern to some of the respondents. As BIM develops across platforms, cloud, tablet and mobile phone, the construction industry will change and in reality they are attempting to, as one respondent put it, *hit a moving target*. This will prove challenging for the pedagogical aspect of BIM as well. Teaching methods will also have to adapt to meet industry's needs.

In the interim some sections of the industry still need to be convinced as to the benefits of BIM and the findings show accreditation panels with little knowledge of BIM should incorporate members with BIM experience. This would give confidence to HEI's who are still unsure as to whether they have adopted the correct approach to BIM teaching and gain the staff buy-in for the adoption of a management system which will see increased use and evolve over the next number of years.

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